Automatic Looting Detection using Machine Learning and Open Source Satellite Imagery

A move towards real time tracking

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Since the early 2000s, the archaeological heritage of the Near East is under an ever increasing threat from a multitude of sources including looting, militarization as well as unplanned urban expansion (Daniels and Hanson, 2015). The vast expanse of land along which these sites are distributed means that physically monitoring each location is impossible, and in many cases, given the current political climate, unsafe. In recent years, the availability of Very High Resolution (VHR) imagery with short revisit times meant that keeping an eye on cultural heritage sites became slightly easier (Casana and Laugier, 2017). However, relying on up to date VHR imagery comes with a high cost, beyond the budgets of most local authorities in the Near East, as well as beyond those of the majority of the larger archaeological bodies. This high cost drove researchers to focus on open source VHR imagery such as Google Earth or similar. The images provided by these platforms are generally outdated by the time they are accessible for free. This means that researchers often monitor the ground situation several years in arrears and are thus not able to properly assess the current situation and devise the necessary protection policies.

This paper proposes a method that aims, on the one hand at cutting the cost of acquiring a constant stream of VHR imagery to remain up to date on the ground situation. On the other, the proposed method aims at automating the process of detecting ground disturbances possibly associated with looting or destruction within archaeological sites, thus limiting the amount of human power needed to monitor huge swaths of land.

The proposed approach relies primarily on data from two European Space Agency (ESA) missions, Sentinel-1 and Sentinel-2. The Sentinel-1 mission comprises a constellation of two satellites (Sentinel-1A and 1B) performing C-band synthetic aperture imaging, which is capable of acquiring radar images regardless of weather (clear, cloudy, etc.) and time (day and night). The Sentinel-2 mission comprises a constellation of two satellites (Sentinel-2A and 2B) providing multispectral high-resolution imagery. In addition to the satellite acquisitions, auxiliary data in the form of land use maps and weather information is obtained.

The satellite data is processed in two main steps. The first includes the creation of Interferometric Synthetic Aperture Radar (InSAR) coherence maps (Figure 1). These maps highlight areas of ground changes which *might* be related to archaeological looting, and are obtained from two subsequent Sentinel-1 acquisitions of the same area from a similar orbital location (for a similar approach see Cigna and Tapete, 2018). An initial map generated over a time period of known site stability (no looting activities) acts as a control map. These maps are then segmented based on their coherence value and thus creating patches of stability (high coherence values - low decorrelation), and patches of likely disturbances (low coherence values - high decorrelation) which include possible looting as well as other natural sources of decorrelation like vegetation, urban construction, and non-looting related human activities. Maps are constantly generated and evaluated as long as the site in question is being monitored.

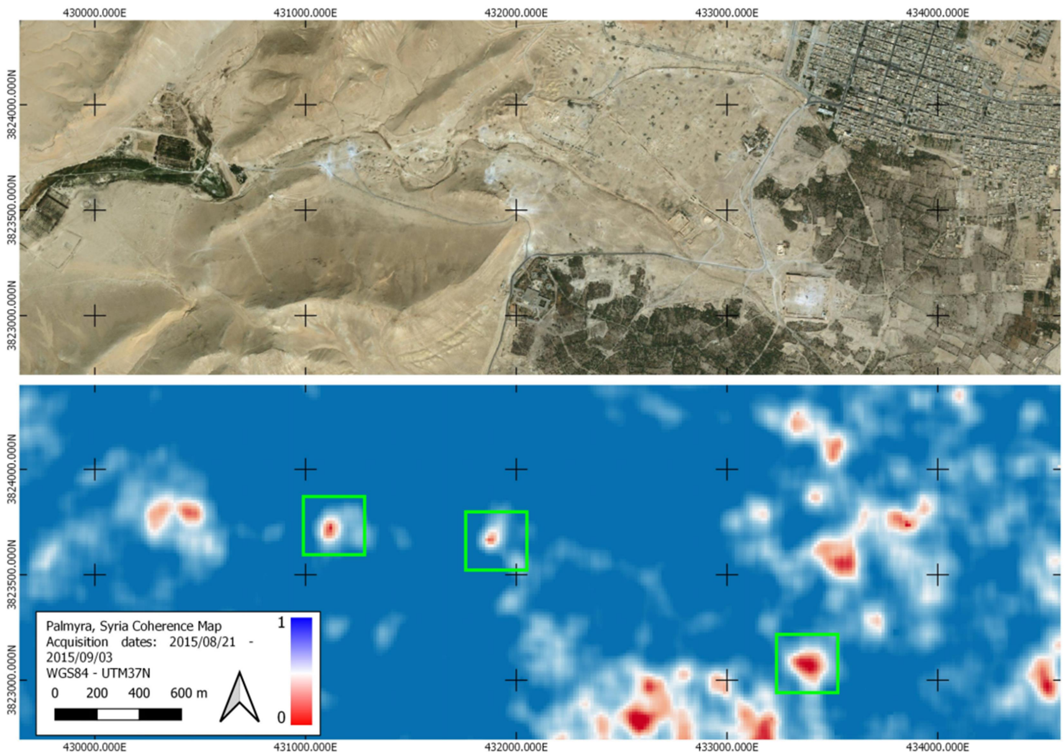

Figure 1 - VHR Image of Palmyra [top] - InSAR Coherence map with marked disturbances [below]

Due to the multitude of sources that can be at the root of the decorrelation, each decorrelated patch is associated with a feature vector that represents it. One of the major entries in the feature vector is the Normalized Difference Vegetation Index (NDVI), derived from the Sentinel-2 acquisitions. This index identifies pixels with healthy vegetation, which is a major source of volumetric decorrelation, and as a consequence False Positives in the identification of looting related patches. In to the NDVI maps, the Sentinel-2 acquisitions are used to generate land cover maps the surveyed areas using unsupervised learning (k-means clustering) and divide them into different classes. Additional auxiliary data in the form of weather data as well as geographic location data of the patch are acquired. Finally, the data products generated from the two sensors are resampled at a resolution of 14 m pixels using bicubic interpolation.

Data is collected from several sites with known looting and destruction events in Syria and Iraq, as well as other sites in the Near East and North Africa where disturbances were recorded. This created a relatively small database with known disturbance patches. The dataset is imbalanced with the majority of the patches in the monitoring areas resulting from non-looting activities. In order to continue with the processing, synthetic data was generated using the Synthetic Minority Oversampling Technique (SMOTE) (Chawla et al., 2002) which increased the number of confirmed looting patches artificially. With a balanced dataset, it is possible to train an *ensemble* of models consisting of support vector classifiers and random forest classifiers on different principal components of the feature vector. It is then possible to obtain good results through majority voting when it comes to detecting True Positive looting patches from the InSAR Coherence Map.

This approach is meant to decouple the process of monitoring cultural heritage sites from its reliance on a constant stream of VHR imagery on the one hand. On the other, the ability of this approach to monitor large swaths of land and return limited patches of potential looting reduces the role of human operators from having to survey large areas visually to simply checking a limited number of patches per coherence map. A wide scale implementation of this method will lead to a better understanding of looting activities on a large scale and the forces driving it in the Near East, and subsequently lead to drafting improved cultural protection policies on the local and international levels.

References

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